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Cultural differences in attention: Eye movement evidence from a comparative visual search task

Albandri Alotaibi [1,2]

Geoffrey Underwood [1]

Alastair D. Smith [1,3*]

1. School of Psychology, University of Nottingham, UK
2. King Saud University, Saudi Arabia
3. School of Psychology, Plymouth University, UK

*Correspondence concerning this article should be addressed to:

Dr Alastair D. Smith, School of Psychology, Plymouth University, Drake Circus, Plymouth PL4 8AA, United Kingdom. Email: alastair.smith@plymouth.ac.uk

Abstract

Individual differences in visual attention have been linked to thinking style: analytic thinking (common in individualistic cultures) is thought to promote attention to detail and focus on the most important part of a scene, whereas holistic thinking (common in collectivist cultures) promotes attention to the global structure of a scene and the relationship between its parts. However, this theory is primarily based on relatively simple judgement tasks. We compared groups from Great Britain (an individualist culture) and Saudi Arabia (a collectivist culture) on a more complex comparative visual search task, using simple natural scenes. A higher overall number of fixations for Saudi participants, along with longer search times, indicated less efficient search behaviour than British participants. Furthermore, intra-group comparisons of scan-path for Saudi participants revealed less similarity than within the British group. Together, these findings suggest that there is a positive relationship between an analytic cognitive style and controlled attention.

Keywords*:* Visual attention; Visual search; Culture; Eye movements; ScanMatch

1. Introduction

Cross-cultural studies of visual perception have revealed numerous examples of cultural diversity (e.g., Kitayama et al., 2003; Chua, Boland, & Nisbett, 2005; Masuda & Nisbett, 2001; McKene et al. 2010). A robust finding appears to be in hierarchical perception, with different groups demonstrating a relative bias towards the global or local level of a stimulus or scene. In particular, it seems that people from an individualistic culture (i.e. one that focuses on the skills and achievements of the individual) demonstrate an analytical style, preferentially attending to focal parts of a visual scene. In contrast, people from a collectivist culture (i.e. one that focuses on group-based membership and collective achievement) appear to demonstrate a holistic style, attending more to the structure of a scene and the relationship between its parts (Chua, Boland, & Nisbett, 2005; Masuda & Nisbett, 2001, 2006; Miyamoto, Nisbett, & Masuda, 2006). Thinking styles tend to correspond to national cultures, with a bias towards individualism in Western countries, and towards collectivism in Eastern countries (Hofstede, 2001).

The majority of these findings have utilised relatively simple judgement tasks, as well as scene perception and recognition tasks. For example, Kühnen, Hannover &Schubert (2001) associated individualistic cultures with more efficient performance on the Embedded Figures Test (EFT: Witkin & Berry, 1975), where participants are required to locate a simple shape embedded in a more complex global structure. This is complemented by studies such as that reported by McKone et al. (2010), who found that East Asian participants (from Hong Kong, China, Singapore, Malaysia, Indonesia, and Korea) showed a stronger global advantage in a Navon task than their Australian counterparts (although see Hakim et al., 2017). Moreover, Masuda & Nisbett (2001) examined whether Japanese and Americans differed in their patterns of attention to the background. Participants were shown animated vignettes featuring underwater scenes. They were asked to describe the content of the vignettes and then to complete a recognition task that consisted of some repeated and some new objects, against either familiar or new backgrounds. The participants were then asked to judge whether they had seen each object during the first inspection. Findings indicated that the Easterners offered more detailed statements about the background, while the Westerners tended to begin their descriptions by referring to the most salient objects. Furthermore, Easterners were much more likely to begin by making a reference to the context, and in the recognition phase, the Easterners' scores were higher for the objects presented in their original backgrounds. In another study that used a preference task followed by a recognition test, American participants appeared to fixate more on focal objects than Chinese participants, and tended to look at them more quickly. In the recognition phase, the Chinese participants were less likely to recognize familiar objects when they were presented in new backgrounds (Chua, Boland, & Nisbett, 2005).

Based on an individualism-collectivism framework, individualistic cultures tend to emphasize personal goals, and encourage the desire to be different, whereas collectivist cultures emphasize the priority of group goals, and value obligations (Hofstede, 2001). Correspondingly, it has been argued that this dimension is reflected in the preferred cognitive styles of individuals - characteristics and social practices relating to culture are seen to influence cognitive development, resulting in the adaptation of independent (analytic)/interdependent (holistic) cognitive styles that, in turn, shape the way the individual responds to his/her environment (Witkin & Asch, 1984).

Interestingly, however, it is unclear whether these cultural differences are observable in more complex visual behaviour, such as search. Visual search is a fundamental daily activity, and has been widely used to provide insight into the guidance and allocation of task-based visual attention for over 30 years (e.g., Gerhardstein & Rovee-Collier, 2002; Donnelly, et al., 2007; Neider & Zelinsky, 2006). As a result, search tasks should provide a more robust test for theories of culture-based differences in everyday visual behaviour. Some headway has been made in the relatively few studies published by other laboratories. For example, Kuwabara & Smith (2012), required American and Japanese preschool children to search a natural scene for a target object placed amongst cluttered distractor objects. American children demonstrated faster search time to find targets, suggesting that their attention might be more focused on individual objects. However, this group difference disappeared when participants performed the same task using 2D artificial stimuli consisting of an array of common objects. In another study, conducted by Masuda & Nisbett (2006), American and East Asian participants were asked to identify the difference between two images in a flicker paradigm, in which the original image and a modified one were repeatedly presented in a sequence, with a blank screen interleaved between each of them. In one condition the difference between the images was at the level of the focal object (e.g., changes in the colour of a vehicle), and in another the difference was at the level of contextual information (e.g., changes in the location of a sidewalk). Analysis revealed that whilst Americans were faster at detecting focal changes, East Asian participants were faster at detecting contextual changes. Again, these differences were related to, respectively, analytical and holistic thinking styles that are seen to be the product of cultural background.

Although search time is a useful assay of attentional processing in these tasks, eye tracking paradigms can provide a finer grain of detail across the time course of a search trial. The particular advantage of measuring eye movements is that one has insight into the spatial and temporal aspects of search behaviour, including the number, duration, and locus of fixations. These properties are known to reflect parametric properties of the search task (e.g., Koerner & Gilchrist, 2008; Vlaskamp & Hooge, 2006) and can also provide us with a clearer assay of regions of the image that different participants preferentially process. In addition, sequences of fixations can be used to produce a scanpath for a given trial, which can reflect the strategies that participants employ (e.g., Locher & Nodine, 1974; Gilchrist & Harvey, 2006) or the systematicity of their exploratory behaviour (Henderson & Hollingworth, 1999; Pellicano et al., 2011). Therefore, in the context of exploring cultural differences in search behaviour, eye movement analyses contribute both a measure of where participants preferentially look, and how systematic (or consistent) that behaviour is across the experiment.

There have been very few published studies of cultural differences that report eye movement data, although one insight was provided by Miellet et al. (2010), who investigated the use of extrafoveal information during visual search. East Asians and Western Caucasians were required to locate animals of different sizes within natural scenes, whilst the display was modulated using a gaze-contingent Blindspot technique (i.e. the foveal portion of the image, at the point of fixation, was removed contingent with the participant's gaze). The size of this deletion was varied between 0°, 2°, 5°, or 8° of visual angle. On the basis of previous findings, the researchers predicted that East Asian participants would be less affected by the loss of foveal information than Western Caucasians. However, they did not find any reliable differences between the groups for search time or eye movement measures in all of the

Blindspot conditions. In contrast, however, analysis of scanpath information using the ScanMatch algorithm (Cristino, Mathot, Theeuwes, & Gilchrist, 2010) provided additional detail. Miellet et al. calculated matching scores for their participants by comparing the scan paths of each participant with all the other participants of the same cultural group (an intra-group comparison), and also calculated inter-group matching scores by comparing the scan paths of each participant of one group with all the participants of the other group. ScanMatch analysis revealed significantly lower inter-group matching scores in the 5° and 8° Blindspot conditions, and also when the target was absent, compared to intra-group comparisons. This demonstrates that the groups were employing reliably different scan paths to inspect the scene, and that this was more consistent within groups. The team attributed this finding to the impact of culture on exploration strategies only in specific conditions, when there were large central scotomas.

Despite these compelling demonstrations of cultural differences in visual attention, there are some important caveats to consider before we construct theories that account for the underlying mechanisms. The first is that such differences are not always apparent in comparative studies. For example, Rayner et al. (2007) investigated the differences between Chinese and American participants in 6 different tasks, including scene perception, reading and visual search. In their case, a conjunction search task required participants to find a brown square target, which was a part of an array of brown circles, and pink squares. They found that the fixation duration did not significantly differ between the cultural groups in the visual search task, and no significant differences were found between the groups in the scene perception task. This suggests that the observation of cultural differences may be task-dependent, even within a behaviour such as search. A second caveat is that the majority of studies seem to rely on Western and East Asian participants to represent, respectively, individualist and collectivist cultures (for an interesting exception to this see Carparos, et al., 2012; 2013). This means that our conception of the interaction between collectivism and attention may be confounded by additional cultural factors that are unrelated to the factor in question.

We aimed to address this latter issue in the present study by comparing visual attentional processing in Western (British) and Arab (Saudi) participants. The lack of research on visual attention and, indeed, cognition in general in Arab culture, is itself an important reason for further research with this population. Moreover, although Arab culture tends to be described as collectivistic (Alamri, Cristea, & Al-Zaidi, 2014; Buda & Elkhouly, 1998; Hofstede, 2001; Sagy, Orr, Bar-On, & Awwad, 2001), it differs from both Western and East Asian cultures on a number of dimensions that could influence visual attention, such as religious beliefs and practices, and the characteristics of the language spoken, both of which being factors that can influence how people inspect the world around them (see Colzato, Wildenberg & Hommel, 2008).

In order to reliably identify any differences between the cultural groups in their searching strategies, we employed a more complex comparative visual search (CVS) task. Whereas the standard visual search task requires participants to maintain a representation of a single target, CVS requires participants to keep two sets of items in mind at the same time, which means there is more load on working memory (Pomplun, Reingold & Shen, 2001). A typical CVS trial consists of a pair of identical images, presented side by side, with one difference between the images – this could be, say, an object, which mismatches its corresponding counterpart along a certain dimension, such as colour, size, or position. Participants are simply asked to search for one difference between the two images on display and detect the mismatch (e.g. Pomplun, Reingold & Shen, 2001; Underwood, Templeman, Lamming, & Foulsham, 2008). In the present study, the location of the mismatching element was manipulated so that it occurred at a focal point of the image, or in the background.

As far as we can determine, no research regarding cultural differences in this specific task has been published. However, based on previous findings reviewed above, it was predicted that if British participants pay more attention to the focal area compared to the Saudi participants (based on their higher tendency to process information analytically) they would show a faster search time, with a lower number and duration of fixations, when the mismatch object was placed in the focal condition. Furthermore, this difference could also occur for background targets, if analytic style favours individual objects over their role within the scene. This was previously found by Kuwabara & Smith (2012), where Western participants were more efficient than East Asian participants in tasks that required participants to attend to a single object and neglect the surroundings. On the other hand, however, if Saudi participants are more sensitive to the background elements then one would expect them to be as efficient as British participants for background objects (i.e. an interaction between group and location). To address these hypotheses we not only analysed behavioural data (i.e. search time and error rates) but also participants' eye movements, with particular focus on when they reliably fixated the target, and how this related to making a response decision. With the target item as our region-of-interest, we explored the mean number and duration of fixations before looking at the target, which can be seen as indices of task difficulty, or search efficiency. We also analysed the number and duration of fixations prior to the final fixation on the target (before generating a response), and the elapsed time between first and final fixations.

Another aim of the present study was to compare the exploration strategies for both cultural groups. In particular, we were interested in how systematic participants' scanpaths were across the course of the experiment, and whether this reliably differed between groups. In order to do so, we implemented the ScanMatch (Cristino et al., 2010) method to compute matching scores between sequences of fixations, across trials. Those scores were then compared both within and between participants groups. This form of analysis was introduced by Miellet et al. (2010) and can be used to explore two issues. First, if the exploration strategies are reliably different between the two cultural groups, then the intra-group scanpath comparisons of Saudi participants and of British participants should yield higher scores than an inter-group scanpath comparison that includes all participants (see Madsen et al., 2012; Miellet et al. 2010). Second, one might predict that an individualistic style would be more likely to yield higher ScanMatch scores, since a systematic approach to search (i.e. a consistent strategy across trials) is thought to be consistent with an analytic cognitive style (Baron-Cohen et al., 2009; Pellicano et al., 2011; Zhang, 2003). Accordingly, we were interested to address whether the British participants showed a reliably higher ScanMatch score than the Saudi group, which might reflect a more ordered approach to visual exploration.

2. Method

2.1 Participants

All participants were recruited and tested in the United Kingdom. Thirty British participants (age *M* = 21.35, *SD* = 2.96, 17 Females) and thirty Saudi participants (age *M* = 24.16, *SD* = 2.79, 16 Females) were recruited for the study. None of the Saudi participants had lived in the UK for more than a year, on average, at the time of the experiment. The British participants were students at the University of Nottingham. Some of the Saudi participants were postgraduate students at the University of Nottingham, and some others were students of the English courses conducted by the University. All of the participants had normal or corrected-to-normal vision. They were paid an inconvenience allowance (£3), or earned course credits, for their participation, and provided informed consent for the study. The experimental protocol was approved by the School of Psychology Research Ethics Committee.

2.2 Apparatus and Materials

Eye movements were recorded with an EyeLink II system (SR Research, Mississauga, Canada), which monitors the position of the pupil in one or both eyes using three infrared cameras mounted on a leather padded headband. In order to minimise head movements, and to ensure a constant viewing distance (57 cm from the monitor), a chin rest was used and participants were asked to remain stationary while performing the tasks. EyeLink II has a high resolution, with noise limited at <0.01°, and a relatively fastest sampling rate (500Hz). Participants responded by pressing keys on a keyboard. The experiment was controlled with SR Research Experiment Builder software.

Visual stimuli were presented on a white background. Sixty-six images were created, each consisting of two real world photographs, arranged side by side. The distance between the edges of each image was set to 3.50 cm. The contents in the stimuli were neutral household items, including kitchen appliances, office stationary, and bathroom accessories. It is well-established that affective content in images has a large impact on the attraction of fixations (e.g. Humphrey, Underwood, & Lambert, 2012), and we therefore chose to display neutral everyday objects to avoid potential confounding factors. The photographs in each stimulus pair differed in terms of the target item, which was placed either in the focal area (33 stimuli) or in the background (33 stimuli), with a distance of 18.6 cm between the target and its correspondent. The size of the images was set to 672 x 869 pixels. Images were taken with a digital camera, held in position on a tripod. Changes to the scenes were made by physically changing the object in the right hand photograph either by removing the target object (target deletion), rotating the target object (target reorientation), or by substituting the target for another object of a similar size (target substitution). There were an equal number of each of these stimulus types (22 stimuli). Examples for orientation focal/ background differences are presented in Figure 1.

----- Insert Figure 1 about here -----

2.3 Design and Procedure

The experiment used a 2 x 2 x 3 mixed design, with a between-subject factor of culture (Saudi and British groups), and within-subject factors of stimulus location (focal and background targets), and change type (deletion, substitution, and reorientation). The dependent variables were: response accuracy; latency to locate the target (i.e. search time); the average number of fixations; the average duration before fixating the target for the first time, and before fixating the target for the last time; and, the ScanMatch analyses of the similarity of visual exploration, both within and between groups.

After a calibration procedure, participants were instructed to search for the difference between the pair of images as quickly as possible. They were informed that each trial contained one difference, and that when they found it they should maintain fixation on the original item (i.e. "stare at the different object on the left hand image"), and press the space bar on the computer keyboard. Thus, any trial with no last fixation on that specific area in the left hand image would be considered an error, as if the participant did not actually detect the difference. Participants were not informed of the possible locations of the difference, or the types of differences they would be searching for. Each trial started with a central fixation point on a white background for 500 ms, this was replaced by a stimulus, and participants were free to inspect it for as long as they needed until they decided to press the space bar. When they did so without looking at the left hand target, they were reminded to do so on the remaining trials. Trial order was fully randomised for each participant. There were six practice trials before the experiment began, and the entire procedure took approximately 20 - 25 minutes to complete.

3. Results

Data points that exceeded a cut-off of three standard deviations above or below the mean were removed as outliers, resulting in the loss of 1.74% of the responses. First, we present accuracy and general RT data, and then we will present the mean number and duration of fixations before looking at the target (in the left-hand images). Mean number and duration of fixations prior to the first fixation on the target were measured as indications of the difficulty level of the task: if the targets were to be easily detected, no valuable eye movement data will be gathered using these measures. We then present the mean number and duration of fixations prior to the last fixation on the target (before generating a response). We also present ‘additional’ search time, since if the time spent between the first and last fixations on the target was equal to zero that would mean the participant detected the target at the first sight. Finally, we present the ScanMatch comparison results.

3.1 Behavioural Data

*3.1.1 Accuracy***.** This was measured by the location of the last fixation (i.e. participants were asked to fixate the target in the “original image” once they had located the difference). If it was around the target’s area on the left-hand image by 2 visual degrees, the response was considered to be accurate. Behavioural and eye movement data from two Saudi participants, who had poor calibration procedures, were omitted as they had missed the location on 13% of the trials. A 2 (group: Saudi, British) x 2 (stimulus location: focal, background) x 3 (change type: deletion, substitution, reorientation) mixed design ANOVA on the percentage of correct answers revealed no significant effect of target location, F (1, 56) = 0.812, $p = 0.37$. In addition, there were no main effects of change type (F (2, 112) = 0.47, $p = 0.51$) or group (F (1, 56) = 0.118, $p = 0.73$) – both groups performed with equal accuracy, M = 94. 25%, SD = 1.05 for the Saudi group, and M = 96.20%, SD = 1.19 for the British group. There was no significant interaction between target location and group (F (1, 56) = 0.81, $p = 0.37$), target location and the change type (F (2, 112) = 1.99, $p = 0.16$), or change type and group (F (2, 112) = 0.44, $p = 0.52$). Finally, the 3-way interaction revealed no significant interaction between target location, change type, and group (F (2, 112) = 1.30, $p = 0.26$).

3.1.2 Search time. Mean search times, for correct trials, were submitted to the same 2 x 2 x 3 mixed design ANOVA model. Analysis revealed a main effect of the target location (F (1, 56) = 227.50, $p < .001$, $\eta p^2=0.83$), with faster search times when the target was in the focal area (M

= 5261.71, *SD* = 2033.21), compared to when it was in the background (*M* = 8958.44, *SD* = 2522.19). There was also a significant main effect of group ($F(1, 56) = 18.55$, $p < .001$, $\eta p^2=0.25$), with Saudi participants demonstrating longer search times (*M* = 7928.47, *SD* = 2833.27) than British participants (*M* = 6291.17, *SD* = 1192.95). There was, however, no interaction between the location of the target and group ($F (1, 56) = 0.75$, $p = 0.33$). In addition, the main effect of change type was not significant ($F (2, 112) = 0.89$, $p = 0.89$) nor there was an interaction between the change type and group ($F (2, 112) = 0.65$, $p = 0.52$). The interaction between the target location, group and the change type was also not significant ($F (2, 112) = 1.31$, $p = 0.27$. However, the interaction between target location and change type was significant ($F (2, 112) = 7.97$, $p < .002$, $\eta p^2=0.13$), as deleting the target took the longest time when it was placed on the background (*M* = 2304.60, *SD* = 784.82) compared to the other two types of changes: *M* = 1931.13, *SD* = 850.24 for target reorientation, and *M* = 1737.23, *SD* = 588.97 for substitution.

3.2 Eye movement analysis

3.2.1 Mean number of fixations before first target fixation. The mean number of fixations before fixating the target for the first time, for correct trials only, were entered into the same 2 x 2 x 3 mixed design ANOVA as above (see Table 1). There was a significant main effect of target location, as the average number of fixations before fixating the focal target was smaller than those before the background target, $F (1, 56) = 179.65$, $p < .001$, $\eta p^2=0.76$. The analysis also revealed a main effect of group ($F (1, 56) = 6.20$, $p < 0.05$, $\eta p^2=0.20$), with the Saudi group generating a higher number of fixations (*M* = 8.70, *SD* = 4) compared to the British group (*M* = 6.52, *SD* = 3.51). There was, however, no significant interaction between target location and group, $F (1, 56) = 2.59$, $p = .11$. Change type did have a significant effect on the mean number of fixations (F (2, 112) = 4.36, $p = 0.02$, $\eta p^2=0.07$) and pairwise comparisons revealed that the number of fixations before fixating the target for the first time in substitution change (M = 7.00, SD = 3.47) was significantly smaller than the other two types of changes: M = 7.93, SD = 3.56, $p < .001$ for deletion, and M = 7.79, SD = 4.73, $p < .001$ for reorientation. There was no significant interaction between the change type and group (F (2, 112) = .24, p = .79), although the interaction between the target location and change type was significant, F (2, 112) = 4.22, p = .02, $\eta p^2=0.07$. The substitution change received the smallest number of fixations before viewing the target when it was in the background (M = 8.60, SD = 3.76) compared to the other types of differences (M = 9.75, SD = 5.44 for reorientation, and M = 10.00, SD = 3.97 for deletion). Finally, there was no significant three-way interaction between target location, group, and change type, F (2, 112) = 2.72, p = .07.

----- Insert Table 1 about here -----

3.2.2 Mean number of fixations before final target fixation. The mean number of fixations before fixating the target for the last time, for correct trials only, is presented in Table 2. For both groups, target location had a significant effect as the average number of fixations before fixating the focal target was smaller than those before the background target, F (1, 56) = 137.32, $p < .001$, $\eta p^2=0.71$. In addition, the data showed a main effect of group (F (1, 56) = 11.76, p = .002, $\eta p^2=0.17$), as the Saudi participants demonstrated a higher number of fixations (M = 11.65, SD = 4.28) compared to the British participants (M = 9.33, SD = 2.86). However, the interaction between target location and group was not significant F (1, 56) = 0, p = 1.00. There was a significant main effect of change type (F (2, 112) = 12.36, $p < .001$, $\eta p^2=0.18$) and pairwise comparisons revealed that the number of fixations for reorientation

(M = 11.60, SD = 4.44) was significantly higher than those of the other two types of changes: M = 10.13, SD = 3.24, p < .001 for deletion, and M = 9.73, SD = 3.78, p < .001 for substitution. The interaction between the target location and the change type was significant (F (2, 112) = 7.71, p = .002, ηp^2=0.12), as changing the orientation received significantly more fixations when it was placed in the background (M = 14.41, SD = 5.85) compared to the other two types of changes: M = 12.86, SD = 3.64, p < .001 for deletion, and M = 11.35, SD = 3.92, p < .001 for substitution. There was, however, no interaction between the change types and group (F (2, 112) = 0.183, p = 0.83), nor was there a significant three-way interaction between target location, group, and change type, F (2, 112) = 1.00, p = 0.26.

----- Insert Table 2 about here -----

3.2.3 Mean duration of fixations before first target fixation. The mean duration of fixations before fixating the target for the first time, for correct trials only, is presented in Table 3. There was a main effect of target location, as the average duration of fixations before fixating the focal target was shorter than those before the background target, F (1, 56) = 6.84, p = .02, ηp^2=0.11. There was, however, no main effect of group (F (1, 56) = 2.17, p = .15) and no interaction between target location and group (F (1, 56) = 0.76, p = 0.39). In addition, there was no main effect of change type (F (2, 112) = 2.99, p = .06) and no interaction between change type and group (F (2, 112) = 0.37, p = 0.70). Finally, there were no significant interactions between target location and change type (F (2, 112) = 1.69, p = .19), or between target location, group, and change type (F (2, 112) = 1.57, p = 0.21).

----- Insert Table 3 about here -----

3.2.4 Mean duration of fixations before last target fixation. The mean duration of fixations before fixating the target for the last time, for correct trials only, is presented in Table 4. There was no main effect of target location, as analysis revealed no significant difference between the average duration of fixations before fixating the focal or the background targets, F (1, 56) = 0.130, p = 0.70. In addition, there was no effect of group (F (1, 56) = 3.15, p = 0.08), and no interaction between location and group (F (1, 56) = 0.53, p = 0.47). There was a main effect of change type (F (2, 112) = 5.40, p < .01, ηp^2=0.09), and pairwise comparisons revealed a significant difference between duration of fixations before fixating the target for the last time for deletions (M = 211.96, SD = 26.60), compared to reorientation, (M = 207.91, SD = 24.63, p < .001) and substitution (M = 206.79, SD = 24.05, p < .001). There were no interactions between change type and group (F (2, 112) = 0.37, p = 0.69), target location and change type (F (2, 112) = 2.94, p = .06), or target location, group, and change type (F (2, 112) =1.13, p = 0.33).

----- Insert Table 4 about here -----

3.2.5 Time between first and final fixations of target. Finally, we tested the time spent between fixating the target for the first time and for the final time in the left-hand image (i.e. the 'original' image). If the target was detected at the first sight, the time between these two measures should be 0. For both groups, the average additional search time was shorter with focal targets (M = 1042.35, SD = 675.47) compared to background targets (M = 1399.55, SD = 961.98), F (1, 56) = 36.73, p < .001, ηp^2=0.39. There was also a significant main effect of group (F (1, 56) = 5.37, p = .02, ηp^2=0.09), with Saudi participants demonstrating longer additional search times (M = 1568.68, SD = 1302.50) compared to the British group (M = 1050.60, SD = 427.25). There was a significant main effect of change type (F (2, 112) = 12.81, $p < .001$, ηp^2=0.28), and pairwise comparisons revealed a significant difference in the time spent between the first and the last look at the reoriented target (M = 1559.55, SD = 919.86), compared to the other two types of changes: M = 1103.93, SD = 769.3, $p < .001$ for deletion, and M = 1008.34, SD = 767.01, $p < .001$ for substitution. The interaction between change type and target location revealed that this finding is more pronounced when the reoriented target was placed on the background (F (2, 112) = 8.36, $p < .001$, ηp^2=0.13), (M = 1915.64, SD = 1178.51), compared to deletion, (M = 1237.74, SD = 859.90) and substitution (M = 1045.27, SD = 847.34). There was, however, no interaction between the target location and group (F (1, 56) = 0.11, p = 0.75), or between change type and group (F (2, 112) = 0.50, p = 0.61). There was no significant three-way interaction between target location, change type and group, (F (2, 112) = 1.72, p = 0.18).

3.3 ScanMatch analyses

Scanpath analysis was performed using ScanMatch (Cristino, et al., 2010), a technique that is based on the Needleman-Wunsch algorithm. It is a method used to quantify the similarity between two sequences of eye movements, and incorporates spatial location, sequential information, and temporal duration to produce a composite score (therefore providing an advantage over other forms of scanpath analysis that do not incorporate fixation duration). Fixations were spatially binned in 16 x 12 bins, with each spatial bin sized 2° high and wide. The substitution matrix was based on the distance between each bin, with a 3.5 cut-off value and a gap value of zero (functional MATLAB code available from the authors on request). A similarity score is the result of comparing the sequences of two eye movements. As a result of normalizing the score of the two sequences, the maximum possible matching score between two sequences of eye movements is 1. A similarity score near to one means that the two sequences of eye movements are very similar, and a score near to zero means that they are very dissimilar.

In order to be able to compare the ScanMatch scores of Saudi and British groups, we created three types of comparison (after Miellet et al., 2010): (a) an intra-group comparison of the Saudi group, named the S–S comparison, which compared the score of each Saudi participant with each participant of his/her cultural group; (b) an intra-group comparison of the British group, named the B–B comparison, which compared the score of each British participant with each participant of his/her cultural group; and (c) an inter-group comparison, named the S–B comparison, which compared the score of each participant from one cultural group with each participant of the other group. These comparisons were carried out for every stimulus, and then averaged across conditions. This approach of arranging ScanMatch data was previously used by Miellet et al. (2010) and Madsen et al. (2012), and it provides a means of comparing the scores of different groups with each other, adding a greater interpretive value to the scores than when comparing them with absolute scale. If the cultural groups tended to search the stimuli differently, then we would expect the inter-group (S-B) scores to be lower than the intra-group (S-S, B-B) scores. Equally, if one group were to search stimuli more systematically (i.e. with a more consistent strategy), then we would expect to see a significant difference in the inter-group (S-B) comparison.

For each target location (i.e. focal and background), separate one-way ANOVAs were conducted to compare the ScanMatch scores for the S–S, B–B, and S–B comparison groups.

There were significant main effects of comparison group for both focal (*F* (2, 1548) = 65.98, $p < .001$, ηp^2=0.09) and background (*F* (2, 1548) = 23.33, $p < .001$, ηp^2=0.30) targets (see Figure 2). Contrasts revealed that the B–B comparisons had statistically higher ScanMatch score in the two target locations: in the focal target condition, this group had a higher score than the S–S comparison group (t (424.01) = -10.104, $p < .001$), and also a higher score than the S–B comparison group (t (1224.449) = 12.01, $p < .001$). Similar results were found for the background condition: the B–B comparison group had higher ScanMatch scores than the S–S comparison (t (455.16) = -5.81, $p < .001$), and a higher than the S–B comparison group (t (1216.23) = 7.36, $p < .001$). These results confirm the fixation data reported above by demonstrating that the British group had higher ScanMatch scores than the Saudi group for both focal and background targets, which is indicative of more systematic and homogeneous search strategies across the group.

----- Insert Figure 2 about here -----

4. Discussion

We examined cultural differences in visual attention by presenting British and Saudi participants with a comparative visual search (CVS) task. The location of the target was manipulated so that it appeared in either the focal region of the image or in the background, and we predicted that British participants would demonstrate greater efficiency for focal targets, whereas Saudi participants would be more efficient for background targets. In terms of behavioural measures, both cultural groups performed the task with equally high accuracy. However, Saudi participants demonstrated slower overall search times than the British group, suggesting lower overall efficiency in the task. Contrary to predictions, there was no difference between groups according to target location: both British and Saudi participants were faster at trials with a focal target, compared to background targets. The group difference in search efficiency may therefore be related to cognitive style, as the analytic style associated with individualist societies (i.e. the British group) has previously been associated with greater focused attention on individual objects and an advantage for directing attention towards task goals. For example, Kuwabara & Smith (2012) and Masuda & Nisbett (2006) both reported relatively longer search times in participants from collectivistic cultures, although the latter study found this pattern only for focal changes, with the opposite pattern reported for contextual changes. Alternatively, the lack of a clear focal/background difference between groups may relate to our use of the CVS paradigm, as opposed to a less complex visual search task. This is a point that we will return to later.

Our eye movement analyses also revealed differences between the two groups. Saudi participants demonstrated a higher overall number of fixations, both before they first fixated the target, and also before they fixated the target for the last time (i.e. before they went on to make a manual response). The fact that we detected group differences before the first fixation on the target indicates that there was a sufficient level of task difficulty in our design. The number of fixations in a search task is thought to reflect task difficulty (e.g., Koerner, Gilchrist, 2008; Vlaskamp & Hooge, 2006) and the greater number of fixations in the Saudi group, along with longer additional searching time, therefore suggests that they found the task more difficult than the British participants.

A further indication of cultural differences in eye movement behaviour can be derived from our analysis of scanpath similarities, both within and between groups. Intra-group comparison of scan paths for Saudi participants revealed a lower similarity score than that of the intra-group comparison of scan paths for British participants. This demonstrates a greater heterogeneity of search behaviour within the Saudi group and, on the other hand, greater homogeneity in exploration and search strategies for the British group. These findings, in general, may indicate that the British participants displayed an object-by-object searching strategy to detect the changes, which has been previously found amongst British participants (Galpin & Underwood, 2005), and which would likely result in the higher similarity scores that we see here. It should be noted that placing the targets in a focal location resulted in greater similarities in searching strategies amongst B-B and S-B comparison groups, although the location of the target did not seem to have an influence on searching strategies for S-S comparison group. This could also be due to greater variability in search behaviour amongst the Saudi group. Previous research has explicitly explored the relationship between behavioural systematicity and an analytical thinking style, and it has been argued that a hallmark of analytical thinking is a consistent, empirically-driven approach to exploring perceptual or conceptual properties of the world (Baron-Cohen et al., 2009; Zhang, 2003). In this case, it appears that British participants were more systematic in their search strategies than Saudi participants, and that there was greater homogeneity within the British group. This could therefore support the assertion that Western society is associated with an analytical thinking style (Chua, Boland, & Nisbett, 2005; Hofstede, 2001; Masuda & Nisbett, 2001, 2006; Miyamoto, Nisbett, & Masuda, 2006), which was here evident in more efficient and systematic search behaviour.

Of course, our current interpretations are conceivably limited by the absence of a measure that explicitly tapped thinking style. As a result, we can only make firm conclusions about the differences between Western and Arab cultures, rather than differences between different thinking styles. Our findings certainly suggest a bias towards a more analytic processing style in British participants, thus conferring greater control for focused attention on individual objects. The ability for individuals with analytic processing style to focus on the task at hand, and to be less distracted by the surroundings, is in line with a previous study by Caparos et al. (2013). They compared Himba and British participants on a Navon-like task that either required detecting the global target and ignoring local distractor, or detecting the local target and ignoring the global distractor. Based on previous findings of local bias in Himba participants, the authors expected this group to be more distracted by the local detail in global selection targets, when compared to the British group. However, they found that the Himba group took considerably less time to accurately detect both the local and global targets, which suggested a greater ability to concentrate on the task at hand. If the differences we observed in the present data were due to greater control of visual search in British participants, future research can directly test this by investigating the link between analytic style and task orientation (e.g. investigating the correlation between performance on an analytic style test and the ability to solve puzzles).

Despite the between-group differences we discovered, there were additional phenomena we observed that were consistent across both cultural groups. First was a tendency to find focal differences more easily than those positioned in the background, since both groups demonstrated faster RTs and a smaller number of fixations when detecting focal changes. One might expect this pattern on the basis of the central tendency bias – a tendency to direct eyes to the centre of the stimuli (Tatler, 2007; Zelinsky & Sheinberg, 1997) – and the data are also in agreement with Rensink's (1997) conclusion that people are likely to detect changes in centre and focal areas faster than the changes in peripheral or background areas. Second, we found that substituting the target with a new similar target seemed to be the easiest difference to detect, whilst changing the orientation tended to be the hardest, based on both RTs and the number of fixations. This finding is consistent with the results of previous research (Hollingworth & Henderson, 2002; Hollingworth, 2002; & Hollingworth, 2003). Detecting the changes in orientation requires memory for the details, as the difference between the original target and the changed one is only in orientation (Hollingworth, 2006).

Overall, our findings reveal that some cultural differences do appear to exist in more complex goal-driven visual-attentional tasks, such as visual search. Interestingly, aspects of these findings are not necessarily consistent with some previous studies. For example, Miellet et al. (2010) found no difference in the number of fixations between Westerners and Easterners, and Masuda & Nisbett (2006) reported shorter search times for Easterners to find contextual changes, compared to Americans participants. The first issue this raises, therefore, is that observed differences between cultural groups may depend on the particular task being administered to participants. To our knowledge, our study is the first to have employed a CVS task, which requires participants to search two separate images and make a perceptual judgement between them. This differs somewhat from a standard visual search task where participants are required to detect the presence or absence of a pre-determined target item, and so the additional requirements of the CVS might task participants differently. In the CVS, the target item is unknown to the participant until they have made a series of comparative object-to-object fixations (Underwood et al., 2008), incurring greater working memory load (Pomplun et al., 2001). This paradigm may therefore engender a shift in the strategies that participants might usually apply to a single array, thus overriding the primacy for focal or background features that are usually evident in other cultural comparisons of search behaviour. The task we present here also utilised novel stimuli that depicted neutral everyday objects, which contrasts to the detection of zoo animals in the study reported by Miellet et al., (2010). Their use of animal stimuli could have made targets more salient to participants (Humphrey, Underwood & Lambert, 2012), and other studies have shown that animals are more rapidly detected than neutral objects, such as plants (LaBue & DeLoache, 2008; Tipples et al., 2002). Our choice of stimuli may therefore have engendered more effortful search for participants which, in this case, seems to confer a relative advantage for Western participants.

The second core issue raised by our findings is that cultural effects may not be entirely commensurate across different groups tested in the literature. The majority of studies addressing tend to compare Western participants with those drawn from East Asian populations. However, although Saudi (and Arab) culture, in general, is reported to be similar to East Asian cultures on the Collectivism-Individualism spectrum (Alamri et al., 2014; Buda & Elkhouly, 1998; Hofstede, 2001; Sagy et al., 2001), Arab culture differs to both Western & East Asian cultures on a number of features. One important component is in religious beliefs and practices, which have been shown to have a meaningful impact of visual attention. Colzato, Wildenberg & Hommel (2008) found that the position toward religion lead to the adaptation of different perceptual strategies, even among the people of the same country. In their study, Calvinists showed a smaller global preference on Navon shapes, comparing to the Atheists. They attributed this result to the Calvinists belief that emphasizes on the independent view of the self and individual responsibility, but then, a question arises about the religious beliefs that might encourage social solidarity (for a review see Colzato et al., 2010). It is unclear whether Muslim culture might itself have effects on visual attention, especially given its strong focus on a group collective, although, in a related domain, de la Fuente et al. (2014) found no difference between Moroccan Muslims and Western participants in a task that exploited cultural beliefs regarding the relative valence of left and right visuomotor mappings.

In our attempts to disentangle these factors, it is important to note that the precise mechanisms by which culture might affect search strategies, and the particular cultural factors that play a role, are still yet to be determined. In contrast to differences in, say, thinking style or religious belief, an alternative explanation for these dissociations is that the physical environment associated with different cultures influences the manner in which people explore their visual environment. Davidoff & colleagues have proposed that the more visually-cluttered the environment is, the wider visual attention is spread, thus decreasing the tendency towards a local thinking style (e.g., Davidoff, Fonteneau, & Fagot, 2008; Carparos et al., 2012). Along these lines, Miyamoto, Nisbett, and Masuda (2006) found that participants who are primed with "Japanese scenes" displayed a reduced change blindness compared to those who are primed with "American scenes". They attributed this result to cultural differences in Japanese and American visual environments, as visual scenes for the former tended to be more ambiguous and cluttered, making it difficult to distinguish focal features from the background. In contrast, American scenes tended to have more clearly segregated environments, with focal objects standing out from their backgrounds. Accordingly, Miyamoto et al. (2006) argued that participants primed with Japanese scenes were more sensitive to changes in the image because the highly dense Japanese environments broadened their visual-attentional span. Although it can be argued that collectivist cultures are more likely to be associated with cluttered visual environments, we cannot necessarily claim the same for Saudi culture. For example, Riyadh, the city where most of our Saudi participants came from, can be described as relatively uncluttered, especially in comparison with the city of Nottingham. It may therefore be the case that an interaction between task, thinking style, and visual environment, is responsible for the observed effects.

Naturally, because we had no direct measure of cultural beliefs and practices, we cannot be certain that either of our groups were completely homogeneous in outlook. In addition, differences in recruitment practices may also have an effect on behaviours observed (see McKone et al., 2010). In our case, there was a higher representation of graduate students in the Saudi group. Not only did this represent a desire to commit to further academic study, but also to do so in another culture, and within a different linguistic context. This may therefore be indicative of particular cognitive and personality traits, such as high levels of ambiguity tolerance and a greater tendency towards an independent thinking style, compared to the average Saudi individual. As such, our sample may not be completely representative of Saudi culture in general, and this a similar caveat for other studies that report cultural differences between home and international students and the same institution. Furthermore, since Caparos et al. (2012) found that brief exposure to an urban environment altered visual processing for Himba participants, the cultural differences we obtained may be more pronounced if we tested a Saudi sample inside Saudi Arabia.

Taken together, the points covered in this discussion give rise to a number of considerations that we intend to take into account in our forthcoming studies. First and foremost, a more comprehensive understanding of visual-attentional behaviour in Arab cultures must come through comparison with other collectivist cultures. Most advances in this area have come about through comparisons between Western and East Asian groups, and a fuller understanding of Arab culture along that continuum will only come by comparing them with both groups. In addition, the context and circumstances within which participants are recruited and tested may also be crucial. Hakim et al. (2017) found out that Chinese participants tested in their home country demonstrated reliable differences from American participants, whereas Chinese participants tested in the US did not (i.e. failing to replicate the findings of McKone et al., 2010). They also discuss the potential top-down influences on performance for participants who are not blind to the fact that they are recruited because of interest in cultural effects on cognition (see also Firestone & Scholl, 2015). With this in mind, future studies of Middle Eastern Arab cultures, for example, should be conducted in their own cultural context, and without explicit reference being made to an experimental hypothesis that is based on cultural performance. Studies such as this will allow us to disentangle the variety of potential influences on visual-attentional performance, which could include individualist/collectivist thinking, religious outlook, environment, and top-down priming.

Naturally, greater knowledge of the mechanisms underlying scene perception in Arab culture will come from the application of a greater variety of experimental paradigms, and we hope that this report of culture-based effects in a Saudi group (see also: Alotaibi, 2016) will inspire more work in this area. Given the relative paucity of behavioural evidence from this group, such research will no doubt be instructive. Greater insight will also come from more sophisticated analyses of eye movements during task performance. We based our study on that of Miellet et al. (2010), using ScanMatch as a means to compare the systematicity of search strategies using a composite measure of eye movements. However, this method (as implemented here) may obscure some of the more subtle components of search behaviour. Alternative analytic approaches, such as that of Jarodzka, Holmqvist, and Nystrom (2010), may provide additional dimensions (including geometric indices of shape) that could further typify performance. Finally, a further possibility for future research is to focus less on differences that are overtly defined by nationality in favour of controlling as much as possible except for the particular variable that predictions are based on. So, for example, one could identify two societies that share similar physical environments, but respectively belong to collectivist and individualist cultures. Equally, one could compare performance across participants from environments that belong to the same culture but have different visual properties. Another useful avenue could be the use of priming methodology to activate a particular thinking style within an individual (Kühnen & Oyserman, 2002; Oyserman & Lee, 2008). One could also activate values that are common to a specific culture by priming participants to those concepts and then testing whether it results in similar behaviours to those observed in different cultural groups. Together, these methods can help us to understand whether perceptual processes can indeed be modulated by a variety of top-down and experiential factors, or whether more stringent criteria must be applied when we build theories based upon demonstrations of apparent cultural difference (Firestone & Scholl, 2015).

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Table 1. Mean number of fixations before fixating focal and background targets for the first time. Standard deviations in parentheses.

	Deletion		Substitution		Orientation	
	Focal	Background	Focal	Background	Focal	Background
British	4.61	8.98	4.91	7.37	5.13	8.12
	(2.93)	(3.90)	(2.72)	(2.84)	(3.70)	(4.97)
Saudi	7.00	11.14	5.33	9.83	6.51	11.38
	(2.91)	(3.80)	(3.52)	(4.23)	(4.31)	(5.50)

Table 2. Mean number of fixations before fixating focal and background targets for the last time. Standard deviations in parentheses.

	Deletion		Substitution		Orientation	
	Focal	Background	Focal	Background	Focal	Background
British	6.15	12.0	6.80	10.1	7.88	12.9
	(1.34)	(3.95)	(2.00)	(3.00)	(2.15)	(4.71)
Saudi	8.67	13.7	9.43	12.6	9.71	15.8
	(3.43)	(3.14)	(4.46)	(4.41)	(3.91)	(6.32)

Table 3. Mean duration of fixations before fixating focal and background targets for the first time. Standard deviations in parentheses.

	Deletion		Substitution		Orientation	
	Focal	Background	Focal	Background	Focal	Background
British	211.68	215.48	209.47	209.89	210.42	214.27
	(31.28)	(29.37)	(30.22)	(24.81)	(32.61)	(28.10)
Saudi	200.94	210.63	199.95	200.93	200.12	205.60
	(22.59)	(25.00)	(22.10)	(19.87)	(19.35)	(21.13)

Table 4. Mean duration of fixations before fixating focal and background targets for the last time. Standard deviations in parentheses.

	Deletion		Substitution		Orientation	
	Focal	Background	Focal	Background	Focal	Background
British	215.74	213.28	211.23	207	210.76	212.88
	(24.40)	(27.47)	(25.00)	(21.64)	(25.79)	(26.42)
Saudi	206.78	212.00	207.46	201.96	202.96	205.36
	(27.89)	(26.79)	(25.61)	(24.29)	(22.82)	(22.67)

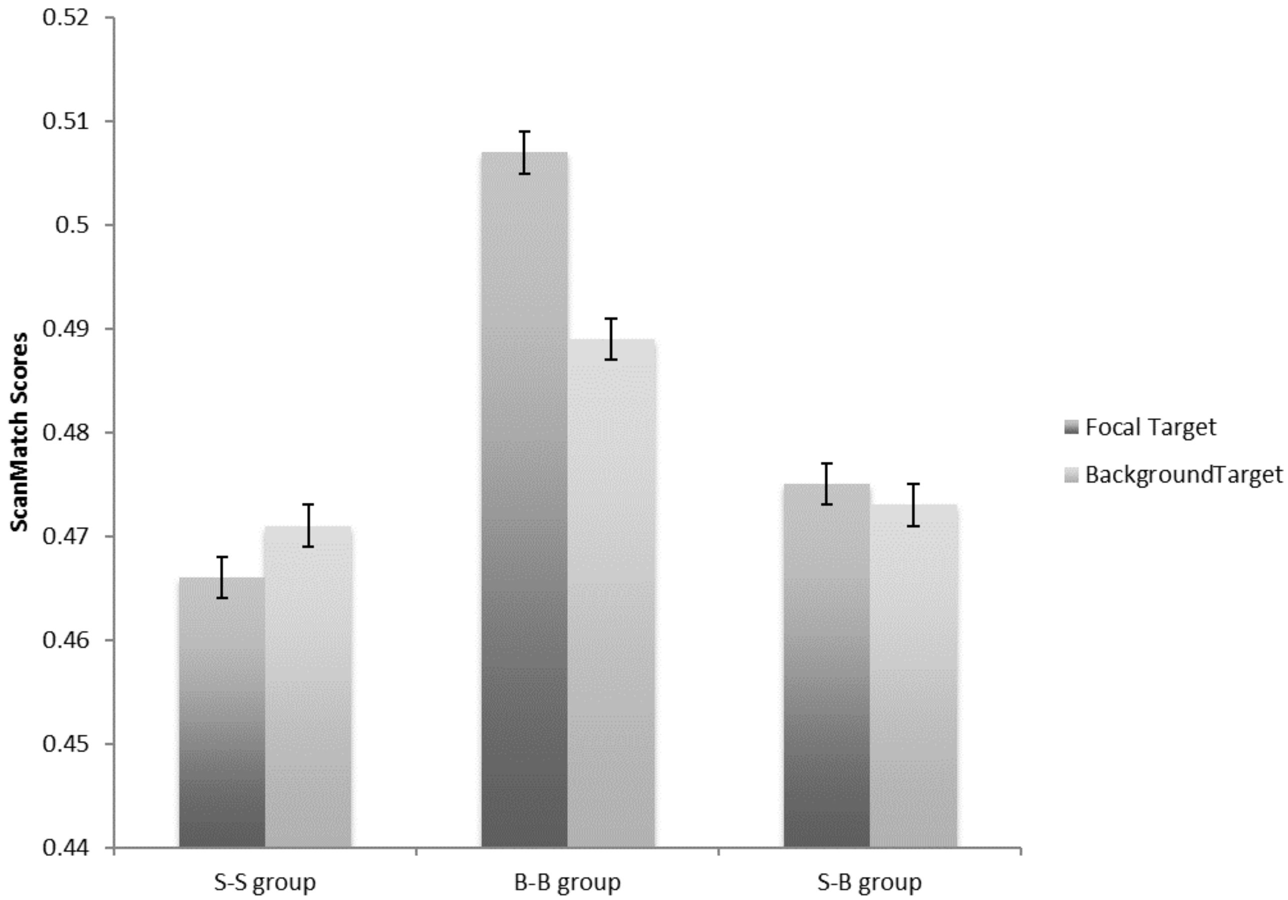
Figure captions

Figure 1. Two examples of stimuli. The top pair illustrates a focal rotation difference, and the bottom pair illustrates a background substitution difference.

Figure 2. Mean ScanMatch scores for Saudi-Saudi (S-S), British-British (B-B), and Saudi-British (S-B) comparison groups. Error bars represent standard error of the mean.

Figure 1.

Figure 2.


0.52
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0.5
0.49
0.48
0.47
0.46
0.45
0.44
ScanMatch Scores
S-S group
B-B group
S-B group
Focal Target
BackgroundTarget